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Equipment Testing

CAPACITANCE BRIDGE BALANCER

by

D. A. Felton and P. G. Frischmann

Report No. 56-RL-1616 September 1956

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CAPACITANCE BRIDGE BALANCER

D. A. Felton and P. G. Frischmann

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ABSTRACT

The addition of a phase discriminator, null-seeking servo loop and read-out facilities to a capacitance bridge permits automatic and rapid plotting of dielectric constant or capacitance and dissipation factor vs any parameter which can be converted to an electrical signal.

CAPACITANCE BRIDGE BALANCER

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INTRODUCTION

Values of dielectric constant and dissipation factor as a function of temperature are necessary for the evaluation of dielectric materials. Obtaining these data is a tedious task, especially for ferroelectric materials whose values change rapidly near the Curie temperature. Three readings--capacitance, dissipation factor, and temperature--must be taken simultaneously at small temperature increments to obtain sufficiently accurate curves. The capacitance values must be converted to dielectric constant and then plotted. Equipment has been designed utilizing a General Radio type 1610-A Capacitance Measuring assembly to plot these data automatically.

SYSTEM OPERATION

The oscillator, bridge, and amplifier shown in the block diagram (Fig. 1) are contained in the General Radio assembly. The additional equipment, except for the Moseley X-Y recorders, is mounted in the same relay rack. The oscillator provides bridge excitation and a reference signal for the phase discriminator.

When the bridge is unbalanced, the error signal can have two components, in quadrature, corresponding to the capacitance and dissipation factor. Because the bridge can be unbalanced in either direction, either component can lead.

The phase discriminator receives the error signal and senses the direction of both components with respect to the reference signal. It then generates d-c signals of polarities and magnitudes proportional to the error signal components. The dissipation factor signal can be reversed to allow the bridge method of measurement to be changed to substitution. These signals drive two servo amplifiers and motors. The motors then drive the bridge balancing controls and read out potentiometers until a minimum error signal is attained.

The read-out potentiometers shown on the block diagram are a 25-turn Helipot to match the capacitance dial and a special single turn potentiometer to match the nonlinear dissipation factor dial. The

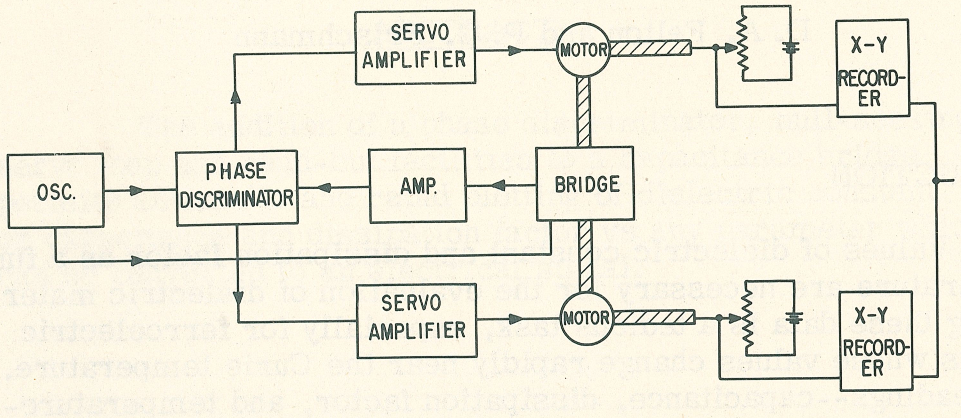
SERVO AMPLIFIER
MOTOR
X-Y RECORDER
OSC.
PHASE DISCRIMINATOR
AMP.
BRIDGE
SERVO AMPLIFIER
MOTOR
X-Y RECORDER

Fig. 1 Block diagram-capacitance bridge balancer.

dissipation factor control has an adder switch associated with it, which is operated by a motor. This motor receives an amplified signal from cam actuated microswitches.

The error of the system when properly set up and calibrated is less than ±1 per cent of full scale for capacitance and ±3 per cent of indicated dissipation factor.

PHASE DISCRIMINATOR AND SERVO DRIVE

Referring to the schematic diagram of the phase discriminator and servo drive, Fig. 2, the reference signal is transformer coupled into a phase shifting circuit to compensate for phase shifts in the bridge and amplifier. The signal is then amplified in V_{1a} and transformer coupled to the deflection plates of V_3. The amplified signal from V_{1a} is also fed through an integrator for a 90° phase shift. The phase shifted signal is amplified by V_{2a} and V_{2b} to its original amplitude and transformer coupled to the deflection plates of V_4. This phase shift is necessary for proper discrimination of the bridge error signal components.

V_3 and V_4 (6AR8's) are sheet beam tubes for gating applications. When a signal is applied to the control grid in phase or 180° out of phase with the deflector voltage, an average d-c potential difference will develop between the plates of the tube. The polarity reverses when the control grid signal reverses in phase. There is no potential difference when the control grid signal is in quadrature with the deflector voltage. Since the deflector voltages of V_3 and V_4 are 90° out of phase, each 6AR8 will respond to only one component of the bridge error signal, thereby providing the necessary discriminating action.

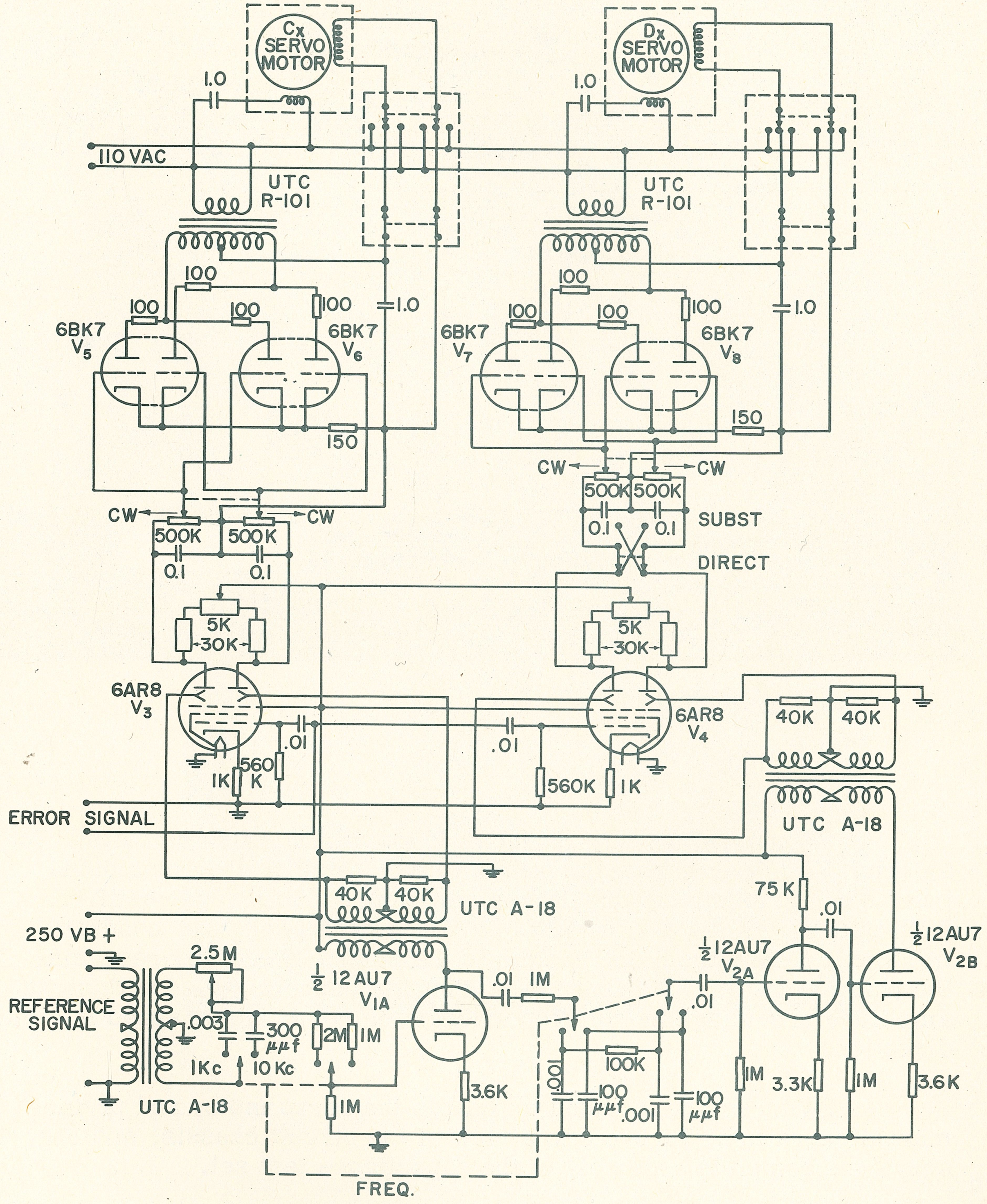
Cx SERVO MOTOR
Dx SERVO MOTOR
1.0
110 VAC
UTC R-101
100
6BK7 V5
6BK7 V6
6BK7 V7
6BK7 V8
150
CW
500K
0.1
SUBST
DIRECT
5K
30K
6AR8 V3
6AR8 V4
.01
560K
1K
40K
UTC A-18
ERROR SIGNAL
250 VB +
REFERENCE SIGNAL
2.5M
.003
300 μμf
1Kc
10 Kc
2M
1M
½ 12AU7 V1A
½ 12AU7 V2A
½ 12AU7 V2B
3.6K
75 K
100K
100 μμf
.001
3.3K
FREQ.

Fig. 2 Phase discriminator and servo drive.

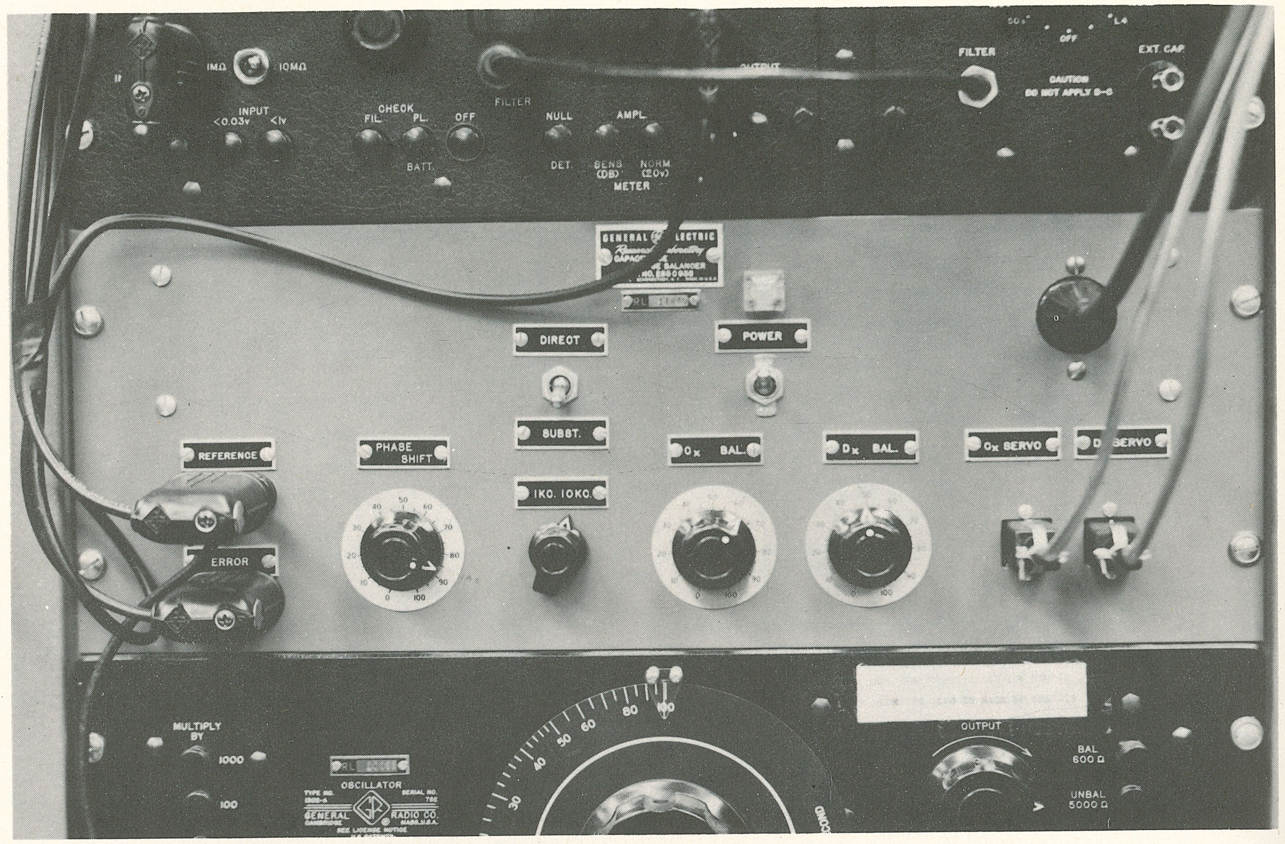

Fig. 3 Capacitance bridge balancer chassis.

V_5 and V_6, V_7 and V_8 are in identical amplifier circuits. Considering V_5 (V_6 is in parallel with V_5) and assuming it to be a diode instead of a triode, the circuit configuration is a full wave rectifier. With triodes, as the d-c signal from V_3 reverses polarity, conduction in V_5 will change from one section to the other, effectively reversing the phase of the load current. Also the load current varies with signal amplitude providing smooth proportional control of motor speed in either direction.

Switches are included to disable the servo motor and provide manual operation. Figure 3 is a view of the circuit chassis, and Fig. 4 shows the complete assembly of the capacitance test set.

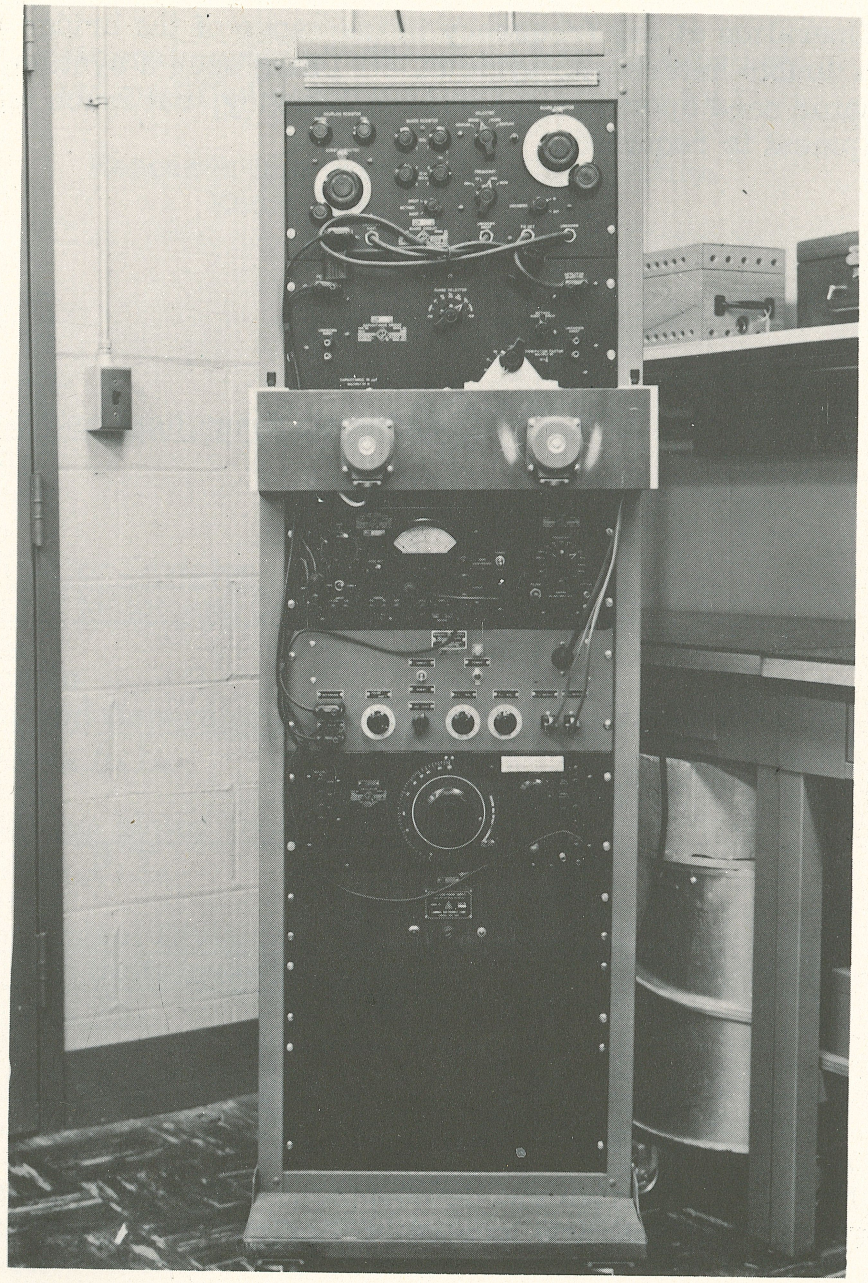

Fig. 4 Complete bridge assembly.

OPERATION AT OTHER FREQUENCIES

The phase discriminator is designed for operation at 1 kc and 10 kc. Other specific frequencies in the audio range may be obtained merely by changing the circuit constants in the phase shifter and integrator. For higher than audio frequencies, the three transformers used would have to be replaced or the circuitry redesigned to operate without transformers.

Operation at any frequency in the range of the bridge is possible by using a double heterodyne system.(1) Using such a system, the phase discriminator need operate at only one frequency, but much more auxilary equipment is required.

ACKNOWLEDGMENT

Much of the design and development of this system was carried out by Bernard Eriksen, now located in Electronics Park, Syracuse.

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(1) Review of Scientific Instruments, Vol. 22, No. 6, 376-383.

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